Technical Report 640

AD-A169 235

The Impact of Personnel Quality on STINGER Weapon System Performance

Abraham Nelson, Edward J. Schmitz, and David Promisel

Manpower and Personnel Policy Research Group
Manpower and Personnel Research Laboratory

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July 1984

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Technical Director

L. NEALE COSBY
Colonel, IN
Commander

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARI Technical Report 640	2. GOVT ACCESSION NO. ADA169235	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) THE IMPACT OF PERSONNEL QUALITY ON STINGER WEAPON SYSTEM PERFORMANCE		5. TYPE OF REPORT & PERIOD COVERED 11/1983 to 5/1984
		6. PERFORMING ORG. REPORT NUMBER --
7. AUTHOR(s) Abraham Nelson, Edward Schmitz, and David Promisel		8. CONTRACT OR GRANT NUMBER(s) --
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Research Institute for the Behavioral and Social Sciences 5001 Eisenhower Avenue, Alexandria, VA 22333-5600		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2Q162722A791
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Research Institute for the Behavioral and Social Sciences 5001 Eisenhower Avenue, Alexandria, VA 22333-5600		12. REPORT DATE July 1984
		13. NUMBER OF PAGES 29
14. MONITORING AGENCY NAME & ADDRESS(If different from Controlling Office) --		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE --

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

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18. SUPPLEMENTARY NOTES

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Weapon system performance
Front end analysis
Man/machine analysis
Reverse Engineering

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Army is currently purchasing many highly sophisticated weapon systems which are designed and developed to achieve certain levels of performance. Since the human is a major component-operator and/or maintainer of a weapon system, he or she should be considered early in the acquisition process. Reverse Engineering is performed on the STINGER weapon system. Using historical performance data on the REDEYE operators who must perform tasks very similar to those performed by the STINGER gunners, and STINGER field tests (Continued)

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ARI Technical Report 640

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data, performance estimates under various scenarios are determined. These performance estimates are then related to human capabilities.

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Abraham Nelson, Edward J. Schmitz, and David Promisel

Submitted by
Curtis Gilroy, Chief
Manpower and Personnel Policy Research Group

Approved as technically adequate
and submitted for publication by
Dr. Joyce L. Shields, Director
Manpower and Personnel
Research Laboratory

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES
5001 Eisenhower Avenue, Alexandria, Virginia 22333

Office, Deputy Chief of Staff for Personnel
Department of the Army

July 1984

Army Project Number
2Q162722A791

Manpower, Personnel, and Training

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FOREWORD

Each year the US Army purchases many new and sophisticated weapon systems. These systems are designed and developed to counter specific threats and are expected to perform at some desired level. Since the human is a major component of most weapon systems, it is important that the individuals who will operate and maintain the systems be considered early on in the acquisition process.

This report uses reverse engineering to explore how the human component of the STINGER weapon system could have been considered in the initial design and development stages of this system. An analysis of the total STINGER weapon system, including the man, is conducted here. Estimates of expected performances for the AFQT categories are determined under various scenarios. This analysis provides an illustration of how and why the individual who will operate and maintain a weapon must be considered early on in the acquisition process of that system.

Edgar M Johnson

EDGAR M. JOHNSON
Technical Director,

THE IMPACT OF PERSONNEL QUALITY ON STINGER WEAPON SYSTEM PERFORMANCE

EXECUTIVE SUMMARY

Requirement:

To determine how and if manpower and personnel issues can be considered early on in the acquisition process of a weapon system.

Procedure:

Reverse engineering is performed on the STINGER weapon system. Performance estimates of the operators of the STINGER are obtained for various scenarios using the STINGER field test data. These data and historical REDEYE performance data, which provides information on the proficiency of individuals operating it as a function of AFQT category, are then used to estimate the performances of the STINGER operators. Total system effectiveness and the human component of it are related to individual capabilities.

Findings:

The AFQT category I-IIIA individuals in the STINGER field tests meet the desired level of performance for only 47 percent of the operative scenarios. The AFQT category IIIB and IV individuals, who comprise approximately 78 percent of the STINGER MOS, are projected to perform below the desired level for <u>all</u> scenarios. Moreover, there is only an 11 percent chance that the current population of the STINGER MOS meets the desired level of performance. Furthermore, it is cost effective to recruit I-IIIA individuals to man the STINGER if the operators launch more than one missile.

This analysis also illustrates that early consideration of manpower and personnel issues were possible for the STINGER. A man/machine trade-off analysis was possible for this system. This means that the performance deficiencies could have been addressed in the initial design and development stages. For example, the AFQT category IIIB individuals in the STINGER MOS could have been replaced by I-IIIA individuals or they could have been provided additional training. Another alternative is to modify the design of the weapon or utilize a combination of these alternatives.

Utilization of findings:

This analysis provides an initial boilerplate for the type of research necessary early on in the acquisition process of a weapon system. It demonstrates the type of feedback between designers and personnel and manpower managers that is needed.

THE IMPACT OF PERSONNEL QUALITY ON STINGER WEAPON SYSTEM PERFORMANCE

CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

This research report describes how personnel quality should be assessed in the design and manning of weapon systems. A specific system (the STINGER) was examined to address the following questions:

- o Can personnel quality be considered in the early stages of system design?
- o Will personnel quality have an impact on the design?
- o How will constraints on personnel quality alter allocation policies?

The results provide an illustrative example of how these questions can be addressed through manpower and personnel planning.

The quality of personnel and its impact on performance is an increasing concern of the Army. Various approaches can be used to examine these issues. For example, the Army can either decrease task complexity or recruit higher quality personnel in order to effectively operate and maintain its weapon systems.

If the quality issue is to be addressed through recruiting policies, the Army needs to know what its quality goals for recruiting should be. Army policymakers must decide how to obtain high quality personnel and allocate them among the military occupational specialties (MOS). To accomplish these objectives the Army needs to know the aggregate personnel quality requirements.

If the personnel quality issue is to be addressed by decreasing the complexity of the tasks required to operate and maintain a weapon system, the design engineers need to know the personnel quality constraints within which they must work. They can then use this information to make trade-offs between equipment complexity and personnel quality. This will allow them to design systems to achieve performance levels which have realistic objectives for human performance.

The need to take personnel quality into account in both the requirements determination and personnel acquisition processes will become exceedingly critical over the next decade. Force modernization is proceeding with hundreds of new systems entering the Army during the next five years. Furthermore, the pool of quality people available for recruiting will decline through the early 1990s because of lower birth rates from 1965-75. Changes in other factors, such as labor demand in the civilian sector, could increase the difficulty of obtaining quality personnel.

Despite the importance of personnel quality to weapon system performance, very little quantitative work has been done on determining the significance of different levels of personnel quality. The Gideon Criterion (J. Wallace, 1981) and the SCACE (Soldier Capabilities and Combat Effectiveness, J. Toomepuu, 1982) are two studies that have been conducted in this area. However, with the exception of the data on personnel cost factors used in the SCACE study, both studies had very limited data on the actual relationship between personnel characteristics and combat performance. This paper, using a particular weapon system, discusses research on how the quality of the personnel required to operate it at an acceptable level of proficiency might have been determined. The STINGER, which is a small portable shoulder fired anti-aircraft weapon is the weapon system considered here. Measures of the total system effectiveness, determined from field tests of this weapon system, are used in conjuction with a training data report (Tubbs, 1981) on the REDEYE, the precursor of the STINGER, to estimate the proficiency for individuals in each AFQT category. These data are used to determine whether the required system effectiveness level can be met with different qualities of personnel.

The second section provides background on the STINGER reverse engineering approach. Section III discusses the approach used to determine personnel quality effects for STINGER, and Section IV summarizes the results obtained. The final section discusses the implications of these results for system design and personnel planning.

II. REVERSE ENGINEERING

The current system acquisition process does not adequately address personnel requirements in terms of quality and/or quantity. This approach could lead to the situation in which the personnel requirements exceed the supply of qualified recruits. It is for this reason that man/machine trade-off analysis (M/MTA) and Front End Analysis (FEA) should be considered early in the system acquisition process. The Army Research Institute for the Behavioral and Social Sciences (ARI) has an ongoing research effort to improve the procedures for determining and evaluating manpower requirements of new weapon systems.

As part of this research, ARI performed an <u>ex post facto</u> man/machine analysis of the STINGER weapon system with emphasis on the M/MTA and FEA aspects. One outcome of the research effort is a determination of whether available performance information could have been used to influence system design. In addition, a personnel performance data base, a baseline for a data base structure, and data sources could be established. As an integral part of this total effort an analysis of the system performance of the STINGER is performed.

III. APPROACH

The purpose of this research was to evaluate the performance of the STINGER weapon system under different scenarios and to relate system performances to human capabilities. The first step was to determine the STINGER weapon system performance specifications. An examination of all relevant documents was then conducted to identify and review performance data. These data were then used to estimate the human component of the total system effectiveness measure. The final and most important step was to relate total system effectiveness and the human component of it to individual capabilities.

The requirements of the STINGER weapon system are stated in the Material Need Statement and the Development Plan. Since many of the requirements of this system are classified, it is not possible to enumerate them here. The

requirements are stated both in terms of the type of targets the system must be able to engage and performance standards of the weapon. For example, the Development Plan states that the system will be designed so that a skilled operator can accomplish all required mechanical operations, from the first step in the firing sequence to fire, within "x" seconds. (This is the system reaction time requirement from threat recognition to missile launch.)

The field tests used in this research are the Contractor Demonstration and the US/FRG (Federal Republic of Germany) tests. Although there are deficiencies in the data collected from these tests, they are sufficiently detailed to permit analysis of performance under several scenarios. These data will allow the estimation of the probability of proper launch against hostile targets under each of the scenarios.

There are five factors used to determine the scenarios in this analysis:

- o Visibility
- o Warning status
- o Engagement sector
- o Aircraft type
- o Flight profile location served as the surrogate measure of visibility.

The Contractor Demonstration test was conducted in an area of the United States where the visibility is good and the terrain is flat. In contrast, the US/FRG(Federal Republic of Germany) field test was conducted under poor visibility in a mountainous region of West Germany. The second factor considered in scenario determination is warning status. If the operator of the STINGER is alerted that a hostile target is approaching, the warning status is "early warning". If there is no alert given to the operator, the warning status is "no early warning." Engagement sector is the third factor used for scenario development. For our purposes, there are two engagement the front quadrasphere and the rear quadrasphere. The fourth factor is aircraft type. In the Contractor Demonstration test the F-7 and the A-91 were used. The F-4 and the German G-91 were used in the US/FRG test. The last factor considered is the flight profiles of the targets. Only three profiles are considered here. They include a non-maneuvering target with and

without off-set and a maneuvering off-set target. An off-set target is one not flying a path which passes directly over the STINGER gunner. All of these factors can substantially affect how well the STINGER will perform.

Not all of the possible scenarios are considered in this effort. Restrictions, which reduce the number of scenarios, are imposed on the factors employed in determining the various scenarios. The first restriction is that only one flight profile is used with the warning status "early warning" in determining scenarios. The second restriction is that either a test or aircraft type, but not both, is used in determining a scenario. As a result of these restrictions 32 different scenarios are possible.

Combining factors, scenarios (which accomodate environmental conditions), target aspect, target speed, engagement sector, and warning status are obtained. For each of the scenarios, the probability of detection, evaluation, and transfer (P_{DET}) is estimated using data from the Contractor Demonstration and the US/FRG tests[1]. This entails determining whether the target is detected or identified, infrared acquisition is obtained, lock-on is accomplished, and engagement of the target within the performance envelope of the STINGER is accomplished. P_{DET} is then the proportion of times that all tasks in the firing sequence are performed correctly with respect to the total number of presentations of targets to the STINGER gunner.

The total system effectiveness measure for the STINGER system has both a human component and a equipment component. Total system effectiveness is defined as:

$$E_S = R_E * P_{DET}$$

where P_{DET} is the human component of the total system performance measure, and R_E measures the effectiveness of the equipment. The effectiveness of the equipment is taken as a given in this case. Given 100 percent equipment effectiveness, the operator performance required to obtain a certain level of

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[1]Since the Contractor Demonstration test did not report its results by aircraft type, it was not possible to analyze this data by aircraft type.

total performance can be determined. Using the Material Needs Statement, in which the required total system effectiveness level is stated, the value of P_{DET} which is necessary to meet the required total system effectiveness can be determined.

Figure 1 (Meister et al., 1965) illustrates how human and equipment performance affects total system performance. The horizontal and vertical axes represent measures of human and equipment performances, respectively. Each curve indicates the relationship between human and equipment performance at certain levels of system performance. Hence this figure depicts total system performance as a function of both human and equipment performances.

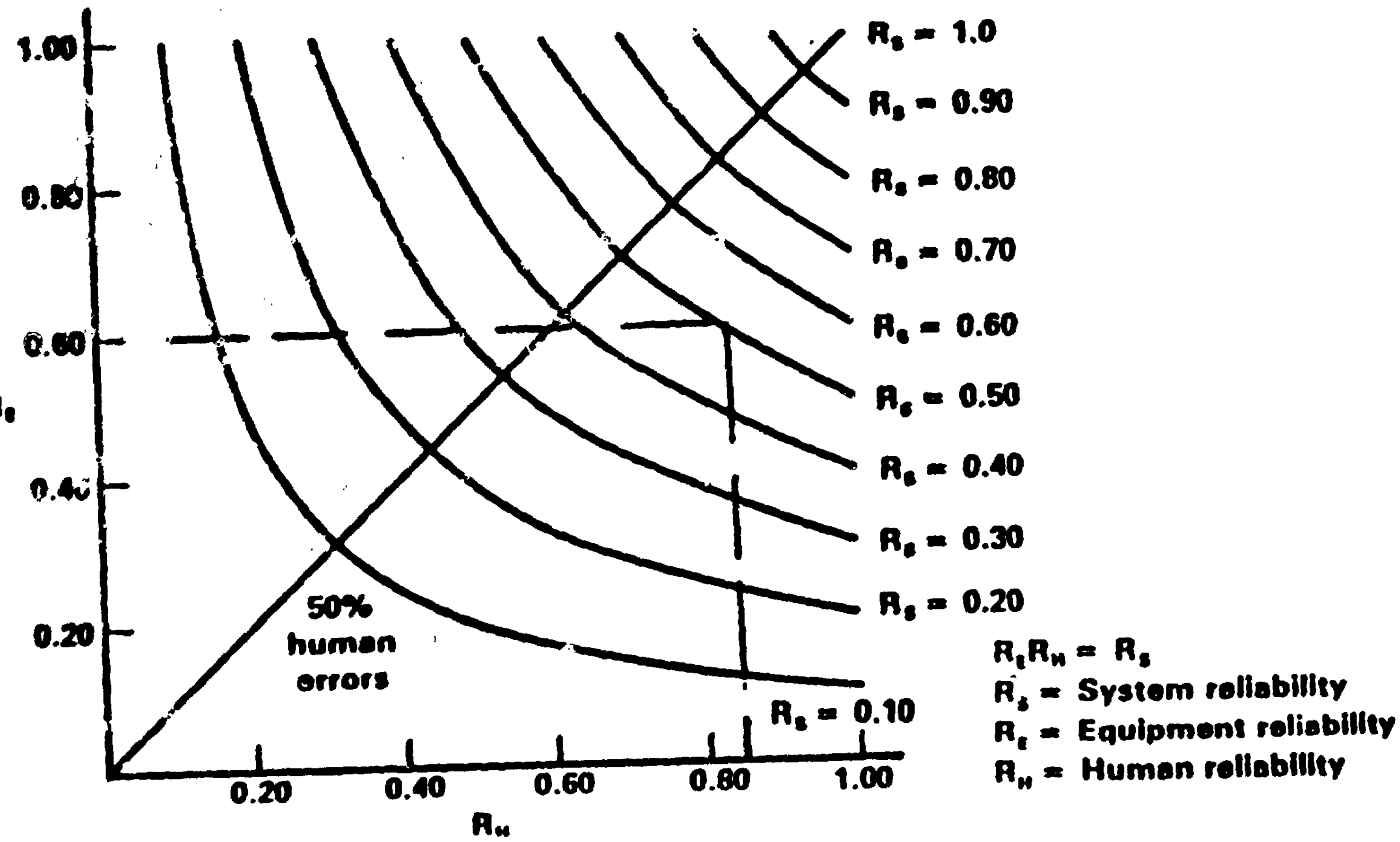
Figure 1 can be used to determine performance levels for one of the components given the other two. For example, assume that the equipment performs at the .60 level and that the desired level of performance for the total system is .50. Using Figure 1, an estimated human performance level of at least .83 is required to meet the above constraints. This means that for the system to perform at the .50 level, given the equipment performs at the .60 level, the probability that an individual performs all actions correctly in the firing sequence of the STINGER must be at least .83.

The Contractor Demonstration and the US/FRG test reports on the STINGER weapon system provide data which allow evaluation of the system operators. These data contain information on each presentation of a target which indicates its flight profile, whether it was engaged or not, and its location if it was engaged. Using these data, it is possible to determine the probability that all tasks in the firing sequence were performed correctly for each scenario.

This means that P_{DET} for the operators is estimated under the various scenarios for the Contractor Demonstration and the US/FRG field tests.

Although several scenarios were used when the P_{DET} were determined, there was no consideration of the differential capability of individuals in these scenarios. The data available from the Contractor Demonstration and the US/FRG tests do not permit such consideration. To compensate for such

FIGURE 1. EFFECT OF HUMAN AND EQUIPMENT RELIABILITY ON SYSTEM RELIABILITY, $R_E \times R_H = R_S$



data deficiency, it is assumed that individuals participating in these tests are in the Armed Force Qualifying Test(AFQT) categories I-IIIA. The AFQT is that section of the Armed Services Vocational Aptitude Battery (ASVAB) used to determine whether an individual is qualified for the service and individuals in AFQT categories I-IIIA are those who score in or above the 50th percentile. AFQT categories IIIB and IV individuals are those who score between the 30th and 50th and the 10th and 30th percentiles, respectively. The above assumption is not necessarily inappropriate since the individuals who participated in these tests were pre-selected for their abilities to perform the firing sequence tasks for which data were being collected.

Using data from the Contractor Demonstration and the US/FRG tests as well as data on the performance of the REDEYE weapon system, the performance levels of AFQT category IIIB and IV individuals on the STINGER are estimated. The US Army TRADOC System Analysis Activity (TRASANA) furnished data on tests conducted on the firing of the REDEYE system in 1980 by individuals in MOS 16P. These data provide information on the REDEYE proficiency of individuals by AFQT category, and are used in this analysis as a performance data baseline for the STINGER system.

The REDEYE weapon system data identify the proficiency of individuals in operating this weapon as a function of AFQT category. The probabilities that the firing steps are performed correctly are available by AFQT categories. Since the tasks performed by REDEYE operators are either the same or very similar to those performed by the STINGER operators, it is possible to extrapolate from the performance of individuals on the REDEYE weapon system to the performance of STINGER operators.

Under the assumption that individuals who participated in the Contractor Demonstration and the US/FRG STINGER tests are in AFQT categories I-IIIA, the performance levels of the AFQT category IIIB and IV individuals are estimated using the REDEYE data. First, the proportion of the performance level that IIIB and IV are of I-IIIA performance level is calculated from the REDEYE data. These percentages are multiplied by the performance levels of operators who participated in the field tests of the STINGER. This provides estimates of the performance of IIIB and IV individuals on the STINGER for each scenario.

IV. SUMMARY OF FINDINGS

This research effort shows the impact on the STINGER system effectiveness of manning the system with operators of different AFQT categories across different scenarios. To illustrate this impact, Table 1 is presented. (It should be noted that data limitations permitted analysis of only 27 of the 32 possible scenarios.) In this table the effectiveness of AFQT category I-IIIA individuals are rescaled to 100 percent. The performance of the other AFQT categories is reported relative to the I-IIIA individuals. For example, Table 1 indicates that when a category IIIB individual operates the STINGER instead of someone in AFQT categories I-IIIA for scenario 1, there is a 13 percent decrease in the P_{DET} estimated.

The degradation of the system varies across the scenarios for both category IIIB and category IV individuals. The percent degradation ranges from 6 to 14 percent for AFQT category IIIB individuals and from 12 to 20 percent for category IV individuals. The median percent decreases in P_{DET} are 13 and 18 for AFQT categories IIIB and IV, respectively. In all scenarios the degradation of the system is substantial when AFQT categories IIIB and IV individuals are employed instead of I-IIIA individuals. This implies that there would be payoffs for better personnel in all cases.

For many scenarios, the projected performance by the operators for the STINGER is not adequate to meet the desired level. The AFQT category I-IIIA individuals in the field tests meet the desired level of performance for 14 out of 27 scenarios, or 52 percent. For the scenarios for which some data did exist, the field test operators reached the desired level of performance for only 47 percent of the scenarios. Moreover, the individuals in AFQT categories IIIB and IV are not projected to meet the desired performance for any of the scenarios.

Although AFQT categories IIIB and IV individuals would not meet the desired level of performance, they currently comprise 78 percent of the STINGER MOS (16S). This implies that 78 percent of the current STINGER operators are estimated to be below the desired level of performance for all

Table 1

The Percent Effective Relative to the I-IIIA AFQT Categories

SCENARIO	AFQT CATEGORY I-IIIA	IIIB	IV
1	100	87	82
2	100	89	85
3	100	89	85
4	100	88	82
5	100	88	83
6	100	86	80
7	100	86	80
8	100	86	80
9	100	92	88
10	100	94	91
11	100	87	81
12	100	88	82
13	100	89	85
14	100	86	80
15	100	86	80
16	100	87	81
17	100	86	80
18	100	87	82
19	100	88	83
20	100	86	80
21	100	86	80
22	100	86	80
23	100	88	83
24	100	86	80
25	100	88	83
26	100	89	85
27	100	87	82

scenarios. In fact, there is only about an 11 percent chance that the current MOS 16S population will meet the desired level of performance for any combination of the operative scenarios.

To further illustrate the impact of manning the STINGER weapon system with different AFQT categories, a cost effectiveness analysis is conducted, the objective of which is to examine the cost of hitting a target with a STINGER for two AFQT groups. Two cost factors -- the cost of recruiting an AFQT category I-IIIA individual and the cost of a STINGER missile -- are considered here. These cost data and the performance on the STINGER during field tests are used to compute the cost of successfully launching one and/or more STINGERs against a hostile target.

Approximate costs are used since exact figures are unavailable. The cost of recruiting I-IIIA individuals is estimated by Armor et al. (1982) at approximately $10,000. The cost of a STINGER is assumed to be $50,000.

In this analysis it is assumed that shots at hostile targets are independent. This implies that the probability of hitting targets has binomial distribution. However, whether or not this distribution or rule is the appropriate model of human performance in this instance is an open which is beyond the scope of this research effort. In order to proceed with the analysis, the probability distribution of hitting targets is assumed to be binomial.

Using the performance analysis for the STINGER, determined earlier in this paper, the probability that a I-IIIA individual hits exactly "n" targets with "n" shots is determined. The earlier analysis also indicates that IIIB individuals perform 13 percent lower than I-IIIA individuals. These performance measures are used with the cost estimates to determine the cost per hit for both AFQT groups. Results are depicted in Figure 2. Figure 3 indicates the relative cost per hit for the two groups. It is clear from Figures 2 and 3 that if the STINGER is to be fired more than once, it is cost effective to man it with I-IIIA individuals.

Figure 2. Cost Effectiveness of the Stinger - Cost Per Hit

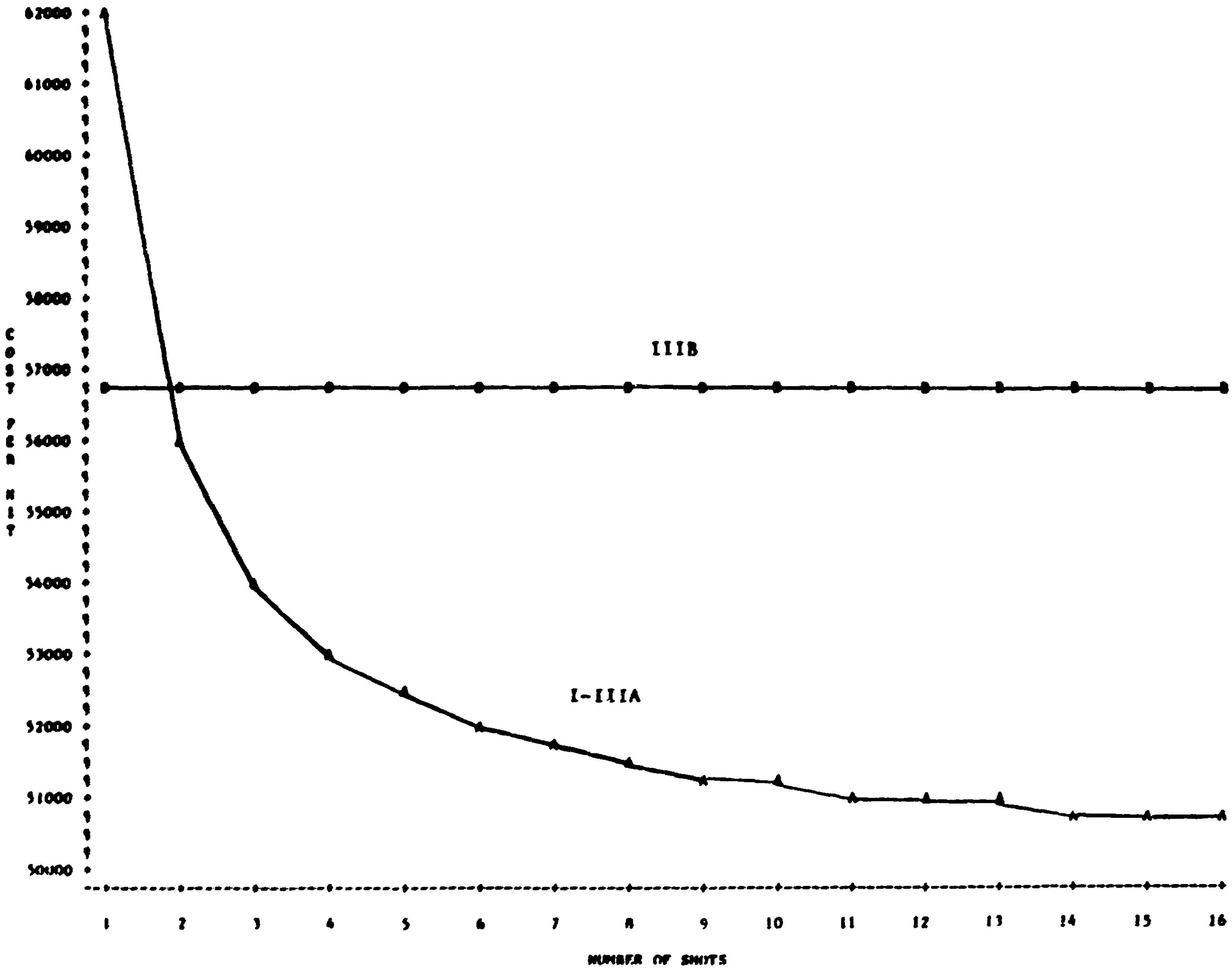
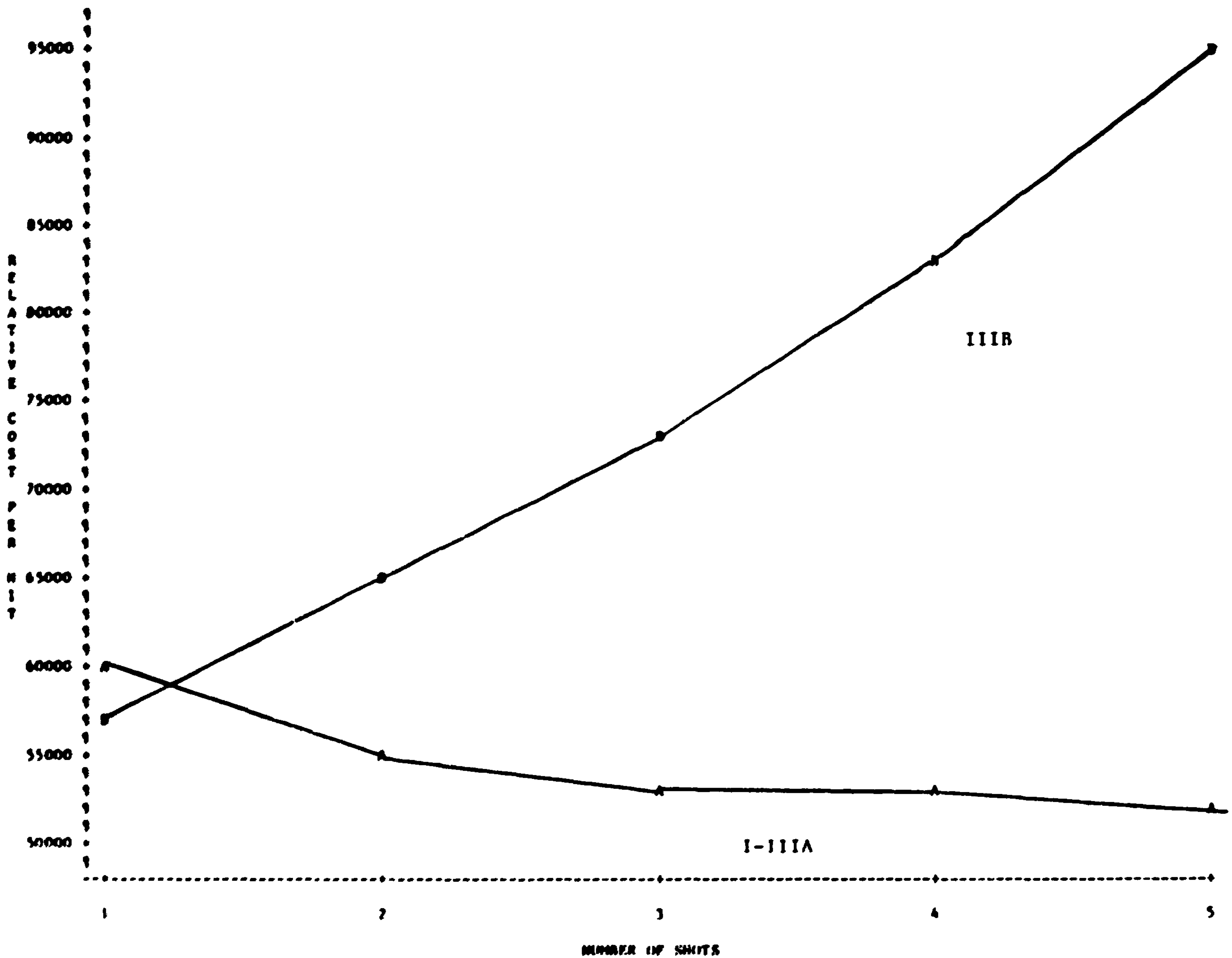


Figure 3. Cost Effectiveness of the Stinger - Relative Cost Per Hit



V. DISCUSSION

The personnel quality requirements of a new weapon system should be considered early in the acquisition process of that system. It is acknowledged that the performance of operators of a system can have a significant impact on the performance of a weapon system. Personnel quality issues, however, were not addressed early in the acquisition process of the STINGER weapon system. The analyses performed in this research effort indicate that high quality personnel are required in the STINGER MOS if the system is to meet or exceed the desired level of total system effectiveness. An analysis, similar to that performed in this research, could have estimated these personnel quality requirements early in the acquisition process of this weapon system.

The total system performance of the STINGER could have been analyzed early in the acquisition process using man/machine trade-off analysis. These analyses could have been employed to increase system performance by either designing the equipment to be less complex, increasing standards for operator personnel, or by a combination of both. Improvement of system performance via the equipment would require the engineers to redesign the weapon to reduce the complexity of the tasks that are performed by the operators. Using this method normally means that the equipment becomes more complex internally, and hence, more expensive. Care must also be taken not to create a system that is easy to operate, but requires high quality personnel to maintain and repair it.

Improving system performance of the STINGER through personnel policy could be accomplished through appropriate recruiting and retention. This might involve the offering of bonuses or other inducements for high quality individuals to enlist and reenlist in MOS 16[illegible]. Such a policy would likely cause additional expenses to be incurred, however. The improvement of the performance of the STINGER could have also been addressed through personnel allocation policies.

It should be noted that the technology used to analyze the STINGER weapon system is not readily transferable to other weapon systems. This is not a typical system in many respects. The fundamental difference is that the only human component in the equation of system effectiveness is the operator component. Most systems require a crew to operate them, while the STINGER can be operated by a single gunner. The analysis of the effectiveness of this weapon system is orders of magnitude less complicated than most weapon systems.

These issues will cause substantially greater analysis problems for other systems. Despite these problems, however, an example of the type of research that needs to be conducted is provided. A demonstration of the need for feedback of personnel factors to designers in the early stages of the acquisition process is also provided. This research effort illustrates the importance of this type of analysis to Army personnel managers in their efforts to improve total Army performance through selection, recruiting, and allocation policies.

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